Electronic Version
Stylesheet Version v1.1.1

Claims

[c1] WHAT IS CLAIMED IS:

1. Apulse frequency modulated (PFM) voltage regulator for converting a DC voltage source to an output voltage,comprising:

a PFM switching controller for generating a PFM switching signal for converting the DC voltage source to the output voltage;

a feedback circuit for generating a feedback signal in response to the output voltage;

a minimum OFF-time controller for providing the PFM switching signal with a predetermined minimum OFF-time; and

an OFF-time prolonging circuit for prolonging the predetermined minimum OFF-time in response to the feedback signal when the output voltage is lower than a predetermined target voltage, whereby:

reducing a ripple of the output voltage.

[c2] 2. The PFM voltage regulator according to claim 1, wherein:

the predetermined minimum OFF-time of the PFM switching signal is prolonged in accordance with an ab-

solute difference between the output voltage and the predetermined target voltage.

[c3] 3. The PFM voltage regulator according to claim 2, wherein:
the predetermined minimum OFF-time of the PFM switching signal is prolonged along with an increase of the absolute difference between the output voltage and the predetermined target voltage.

[c4] 4. The PFM voltage regulator according to claim 1, wherein:
the predetermined target voltage is a DC component of the output voltage.

[c5] 5. The PFM voltage regulator according to claim 1, wherein:
the PFM voltage regulator is operated in a heavy loading condition.

[c6] 6. The PFM voltage regulator according to claim 1, further comprising:
a power switch transistor controlled by the PFM switching signal such that the power switch transistor is turned on during an ON-time of the PFM switching signal and is turned off during an OFF-time of the PFM switching signal, in which the ON-time is shorter than or equal to a

predetermined constant ON-time and the OFF-time is longer than or equal to the predetermined minimum OFF-time.

[c7] 7.The PFM voltage regulator according to claim 1, wherein:
the minimum OFF-time controller includes:
a capacitor, and
a minimum OFF-time setting current source for charging the capacitor such that the predetermined minimum OFF-time is determined by a charging period necessary for raising a potential difference across the capacitor from zero to a predetermined reference voltage, and
the OFF-time prolonging circuit prevents at least one part of the minimum OFF-time setting current source from charging the capacitor in response to the feedback signal when the output voltage is lower than the predetermined target voltage, thereby prolonging the predetermined minimum OFF-time.

[c8] 8.The PFM voltage regulator according to claim 7, wherein:
the OFF-time prolonging circuit includes:
a prolonging reference voltage set lower than a target feedback signal, the target feedback signal being generated by the feedback circuit in response to the predetermined target voltage, and

a differential current pair for determining a sinking current in accordance with an absolute difference between the feedback signal and the prolonging reference voltage such that the sinking current is used for prolonging the predetermined minimum OFF-time when the feedback signal is lower than the prolonging reference voltage.

[c9] 9.The PFM voltage regulator according to claim 8, wherein:
the lower the feedback signal is than the prolonging reference voltage, the larger the sinking current is.

[c10] 10. A pulse frequency modulated (PFM) voltage regulator, comprising:
an inductive means coupled to a DC voltage source;
a capacitive means having a terminal coupled to the inductive means and providing an output voltage;
a PFM switching controller for generating a PFM switching signal for converting the DC voltage source to the output voltage;
a feedback circuit for generating a feedback signal in response to the output voltage;
a minimum time controller coupled to the PFM switching controller, for controlling a minimum time of each period of the PFM switching signal spent on delivering energy from the inductive means to the capacitive means; and
an time prolonging circuit for prolonging the minimum

time spent on delivering energy from the inductive means to the capacitive means in response to the feedback signal when the output voltage is lower than a predetermined target voltage.

[c11] 11.The PFM voltage regulator according to claim 10, wherein:
a ripple of the output voltage is reduced by using the time prolonging circuit.

[c12] 12.The PFM voltage regulator according to claim 10, wherein:
the minimum time spent on delivering energy from the inductive means to the capacitive means is prolonged in accordance with an absolute difference between the output voltage and the predetermined target voltage.

[c13] 13.The PFM voltage regulator according to claim 12, wherein:
the minimum time spent on delivering energy from the inductive means to the capacitive means is prolonged along with an increase of the absolute difference between the output voltage and the predetermined target voltage.

[c14] 14.The PFM voltage regulator according to claim 10, wherein:

the PFM voltage regulator is operated in a heavy loading condition, and

the predetermined target voltage is a DC component of the output voltage.

[c15] 15.The PFM voltage regulator according to claim 10, wherein:

the minimum time controller includes:

a setting capacitor; and

a setting current source for charging the setting capacitor such that the minimum time spent on delivering energy from the inductive means to the capacitive means is determined by a charging period necessary for raising a potential difference across the capacitor from zero to a predetermined reference voltage, and

the time prolonging circuit prevents at least one part of the setting current source from charging the capacitor in response to the feedback signal when the output voltage is lower than the predetermined target voltage, thereby prolonging the minimum time spent on delivering energy from the inductive means to the capacitive means.

[c16] 16. The PFM voltage regulator according to claim 15, wherein:

the time prolonging circuit includes:

a prolonging reference voltage set lower than a target feedback signal, the target feedback signal being gener-

ated by the feedback circuit in response to the predetermined target voltage, and

a differential current pair for determining a sinking current in accordance with an absolute difference between the feedback signal and the prolonging reference voltage such that the sinking current is used for prolonging the minimum time spent on delivering energy from the inductive means to the capacitive means when the feedback signal is lower than the prolonging reference voltage.

[c17] 17. An OFF-time prolonging circuit for a pulse frequency modulated (PFM) voltage regulator, the PFM voltage regulator converting a DC voltage source to an output voltage by using a PFM switching signal having a predetermined minimum OFF-time, the output voltage having a DC component equal to a predetermined target voltage, the OFF-time prolonging circuit comprising:

a feedback signal indicative of the output voltage, in which the feedback signal is referred to as a target feedback signal when the output voltage is equal to the predetermined target voltage;

a first reference voltage set lower than the target feedback signal; and

a first differential current pair for determining a first sinking current in accordance with an absolute difference

between the feedback signal and the first reference voltage such that the first sinking current is used for prolonging the predetermined minimum OFF-time when the feedback signal is lower than the first reference voltage.

[c18] 18.The OFF-time prolonging circuit according to claim 17, wherein:
the lower the feedback signal is than the first reference voltage, the larger the first sinking current is.

[c19] 19.The OFF-time prolonging circuit according to claim 17, further comprising:
a second reference voltage set lower than the first reference voltage, and
a second differential current pair for determining a second sinking current in accordance with an absolute difference between the feedback signal and the second reference voltage such that the first and second sinking currents are used for prolonging the predetermined minimum OFF-time when the feedback signal is lower than the second reference voltage.

[c20] 20. The OFF-time prolonging circuit according to claim 17, wherein:
the predetermined minimum OFF-time is set as a period necessary for raising a potential difference across a capacitor from zero to a predetermined voltage by using a

charging current, and

the first sinking current is used for reducing the charging current.